System Impacts of an Electric Fleet Cluster on the Distribution Grid

Shyamal Patel, Senior Consultant - Hitachi Energy

CIGRE GOTF Conference

National Grid

Hitachi Energy

Acknowledgement

HITACHI
Inspire the Next

Acknowledgement of people who contributed to this study:

National Grid:

- Gideon Katsh
- Jeffrey Wilke
- John McDaniel
- Kelly Stropp
- Brian Yung
- Kaitlyn Meyer
- Brian Johnson

Hitachi Energy:

- Jonathan Hou
- Shyamal Patel
- Gary Rackliffe
- Michael Ziemann
- Christian Pierce

Previous CIGRE publications:

- Sensitivity analysis of the fleet charging impact on feeder load.
- Impacts of Fleet Electrification on Grid Infrastructure

Presentation Outline

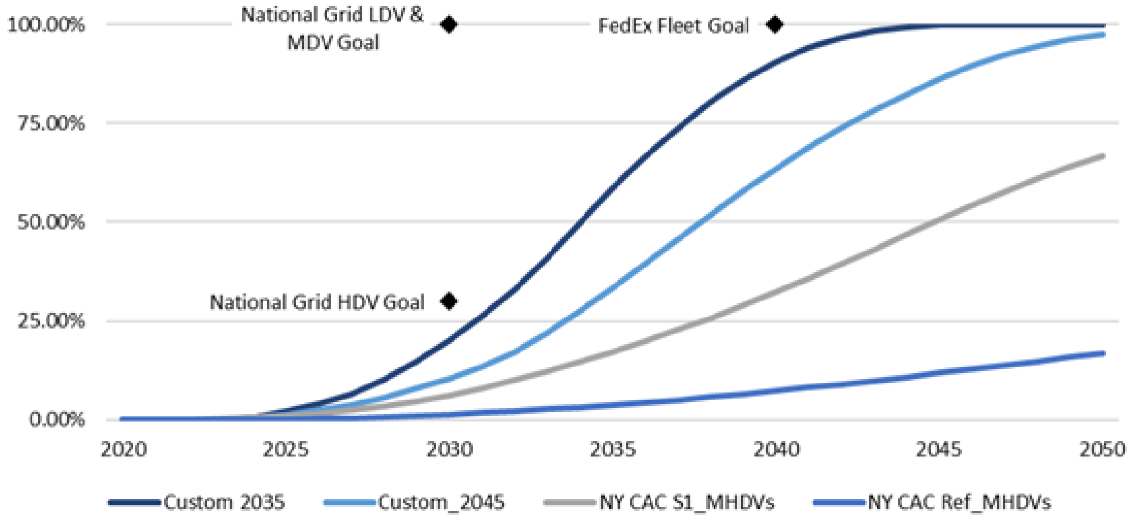
- Introduction: Fleet electrification
- Methodology: Overview of Fleet Charging Load Modelling
- Case Study: Overview
- Impact Analysis: Feeder Overload, Undervoltage, Active power losses, Substation overload, transmission line impacts
- Mitigation options
- Conclusions

Introduction: Fleet electrification

HITACHI
Inspire the Next

Motivation for the fleet electrification

- Medium and heavy-duty vehicles GHG contribution➔23%*
- Push to decarbonize of the transportation sector.
- Fifteen states and the District of Columbia have pledged for 100% zero-emission MHDV sales by 2050 (30% by 2030) with 37 businesses issuing letters of support.
- Fleets offer a substantial return on investment when it comes to decarbonization.



*Nadel, S., and P. Huether. 2021. Electrifying Trucks: From Delivery Vans to Buses to 18-Wheelers. Washington, DC: American Council for an Energy-Efficient Economy. www.aceee.org/research-report/t2102

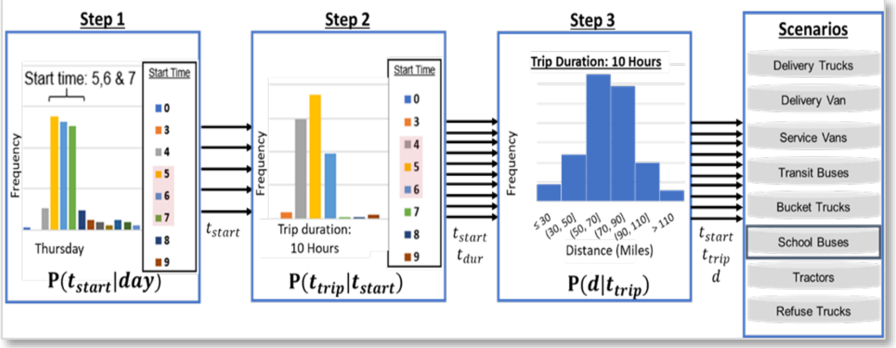
Methodology: Overview of Fleet Charging Load Modeling

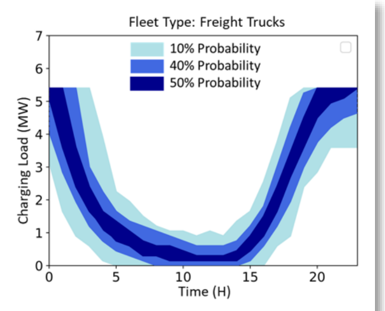
HITACHI
Inspire the Next

Monte Carlo simulation used to evaluate fleet schedules

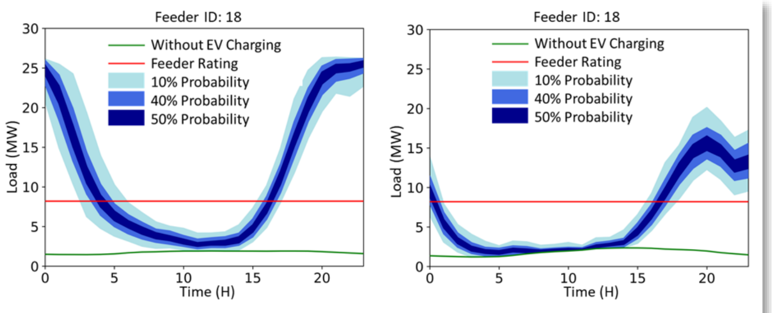
Fleet schedules used to develop charging profiles

Charging profiles mapped to nearest feeder and aggregated to determine load impact





(a) Winter-Full Charging Strategy



(a) Winter-Full Charging Strategy (b) Summer-Full Charging Strategy

Variables for each vehicle's trip ➔ start time, duration, and distance traveled

Charging profiles dependent on:

- Seasons: Summer and Winter
- Charging Strategies: Full Charging & Minimum Charging
- Fleet Type: Class 3-8

51 Fleets mapped to 19 Feeders:

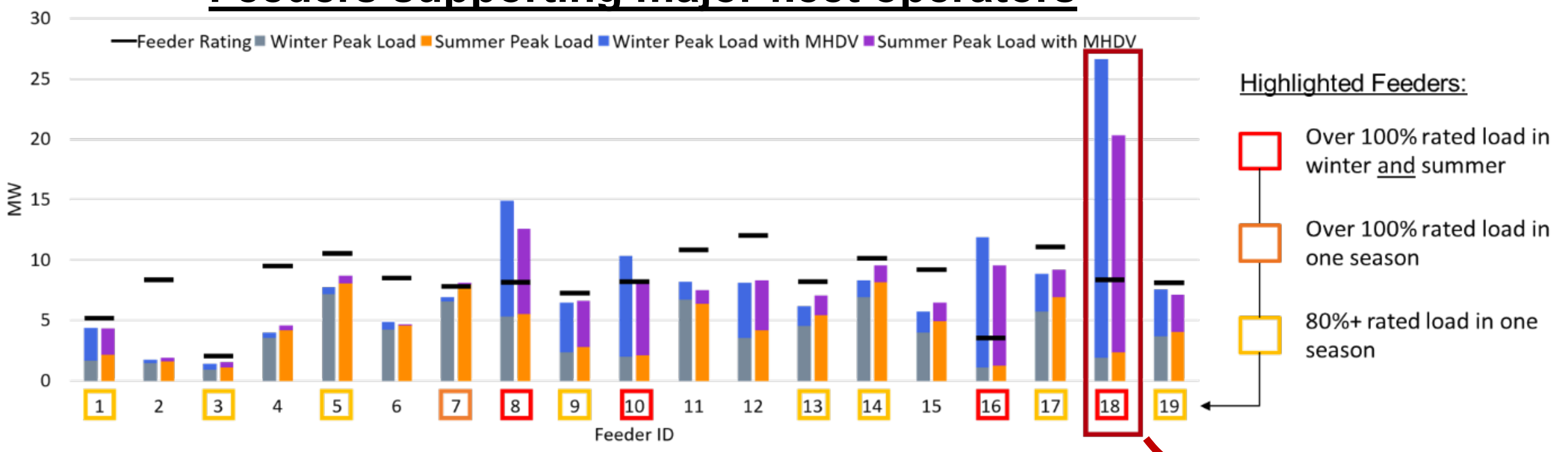
- Load impact determined for the various charging profiles of each fleet

National Grid Hitachi Energy

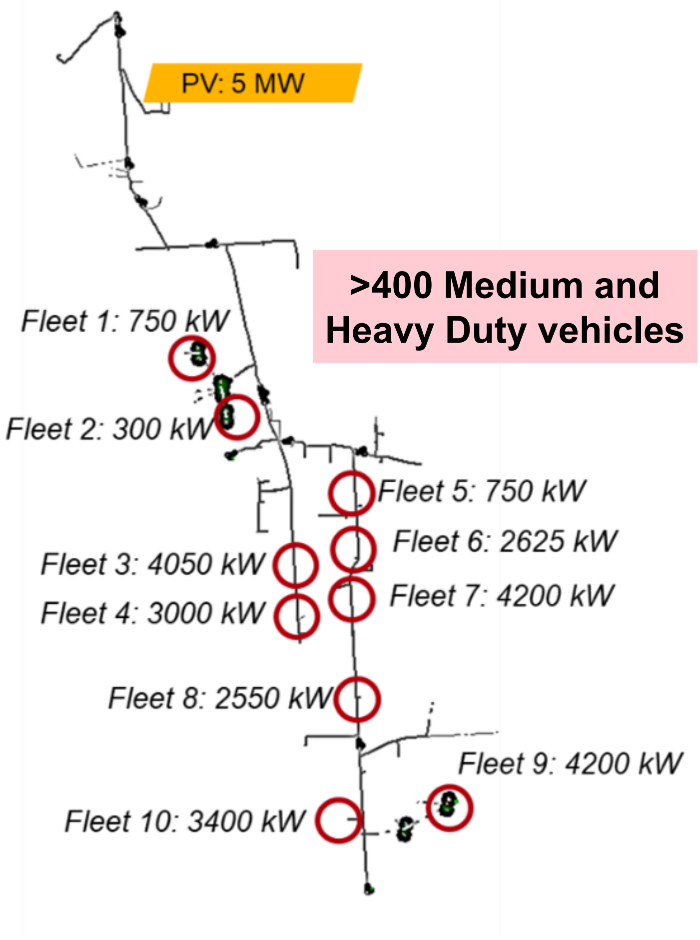
Case Study: Overview

HITACHI
Inspire the Next

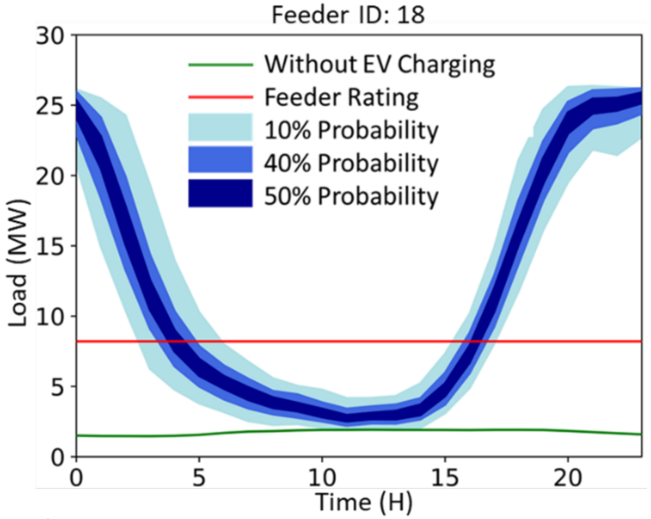
Feeders supporting major fleet operators

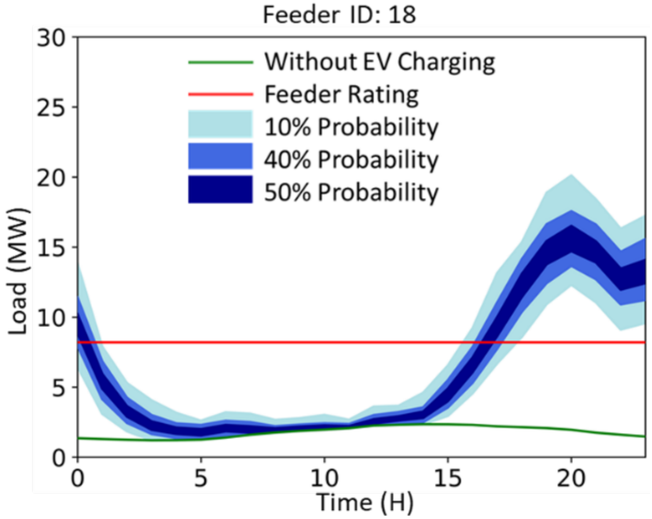


Fleet locations on feeder 18



Load profiles with fleet charging load

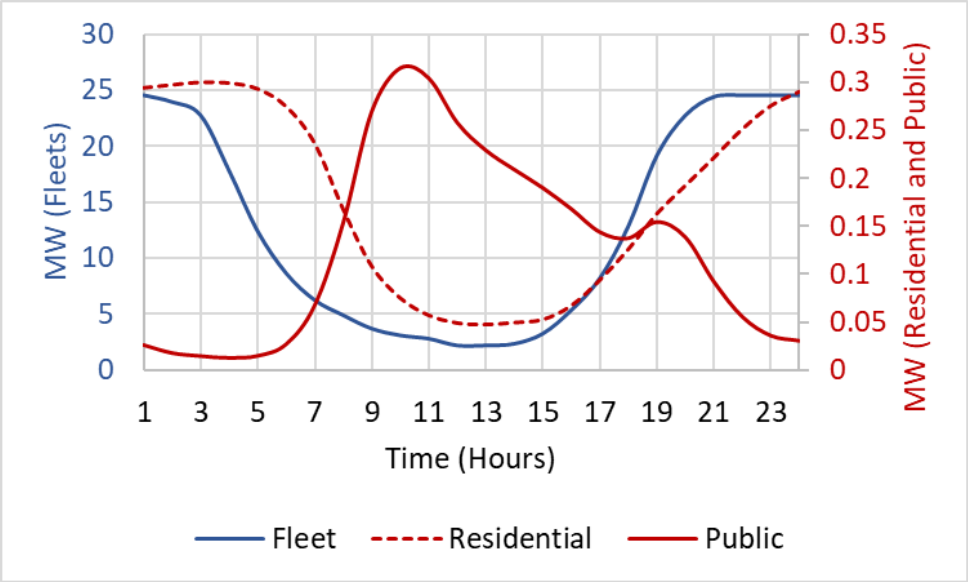




National Grid Hitachi Energy

Case Study: Overview

- Feeder 18 shares the substation transformer with 3 additional feeders.
- Feeder voltage level: 13.2 kV
- Rated capacity of the feeder:
  - 8.2 MW (Summer)
  - 9.85 MW (Winter)
- Current peak feeder loading: ~2 MW
- Existing and upcoming DERs: 5 MW PV + Storage
- Forecasted Fleet load at 100% electrification: ~25 MW (for 10 Fleets with >400)
- Forecasted Public Charging Load: 0.32 KW
- Forecasted residential charging load: 0.3 KW

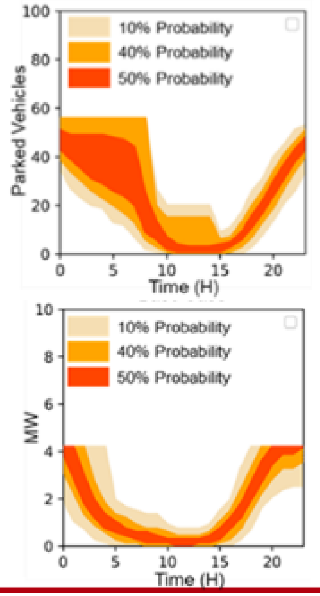


Impact Analysis: Approach

HITACHI
Inspire the Next

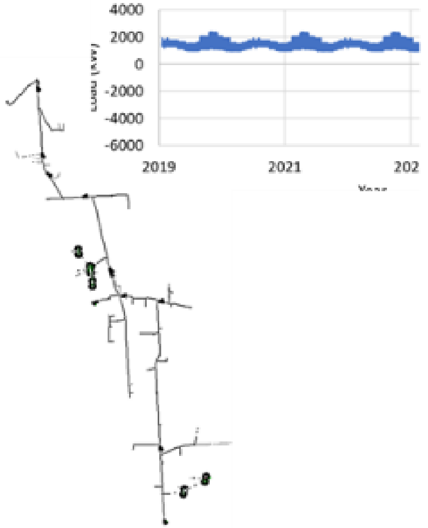
Step: 1

Charging load estimation



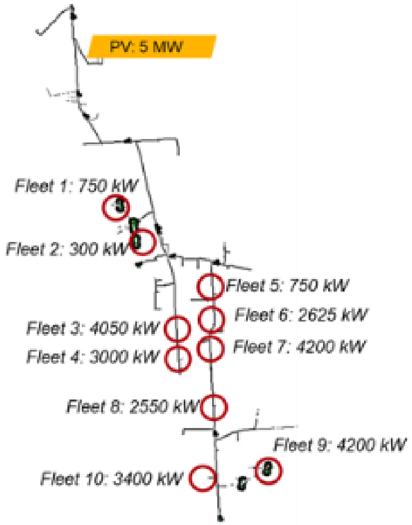
Step: 2

Set-up the peak load condition on the feeder



Step: 3

Represent charging as a spot loads



Step: 4

Perform incremental impact analysis

Run powerflow

Increment the EV penetration by 33%

Node voltage

Powerflow

Line Loss

National Grid Hitachi Energy

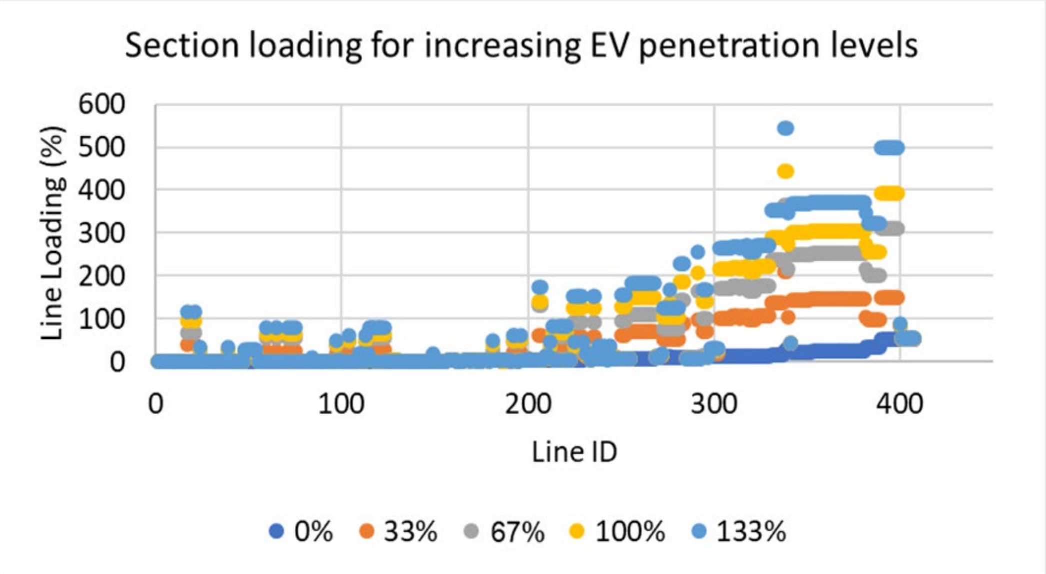
Impact Analysis Results: Feeder Overload

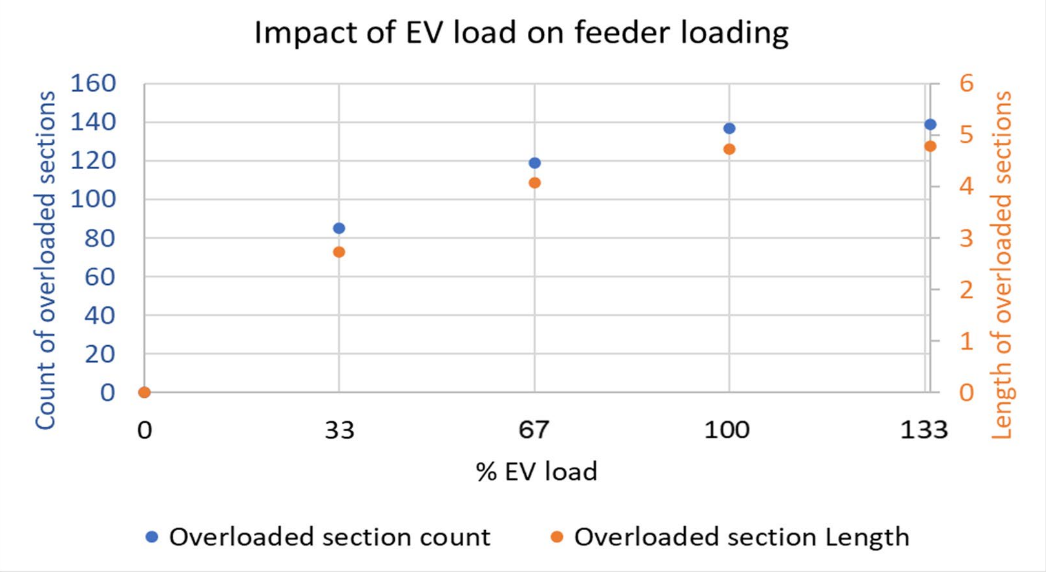
HITACHI
Inspire the Next

- Currently, the feeder is lightly loaded with 2MW of the commercial and industrial loads and does not experience any immediate thermal violations.
- At 33% EV penetration, 88 sections are violated with a total length of 2.4 miles.
- At 100% EV penetration, all upstream sections (total length of 4.72 miles) violate the thermal limits by >444%.

Table: Feeder overload for increasing EV penetration level

Penetration level	Affected length (miles)	Overload %
33%	2.42	Up to 209%
67%	3.82	Up to 364%
100%	4.72	Up to 444%
133%	4.72	Up to 544%





National Grid Hitachi Energy

Impact Analysis: Undervoltage

HITACHI
Inspire the Next

- Feeder 18 has no downstream voltage regulating device.
- The feeder head voltage recommended level is 1.025 pu.
- The voltage violations are observed at selected downstream nodes for 33% level EV penetration. This voltage drops can be regulated using regulators or capacitors.
- Voltage dips below 0.9 pu for >67% EV penetration on majority of the feeder nodes. This voltage dip cannot not be improved through the voltage regulating device.
- The lower voltages on the distribution system ➔Higher losses

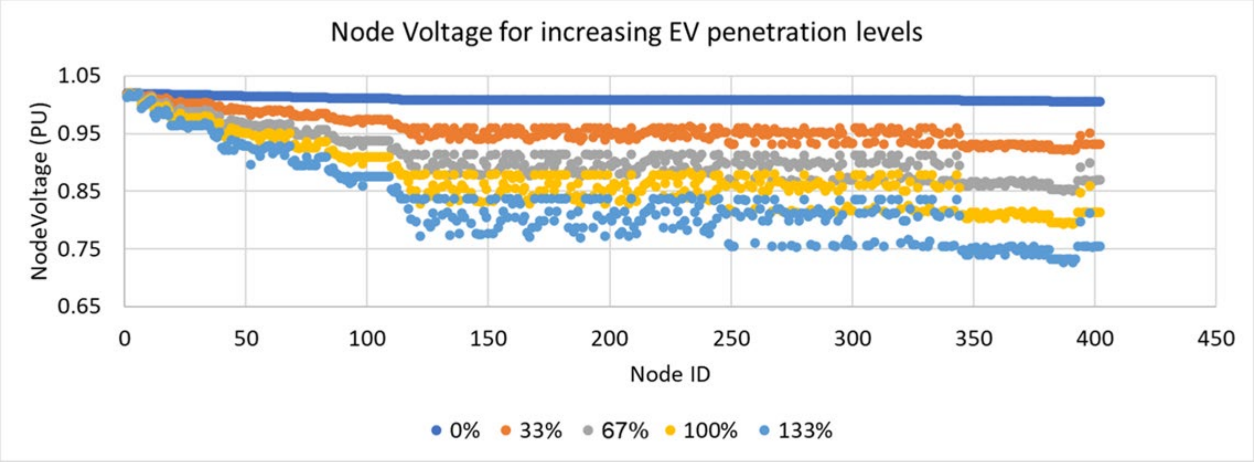
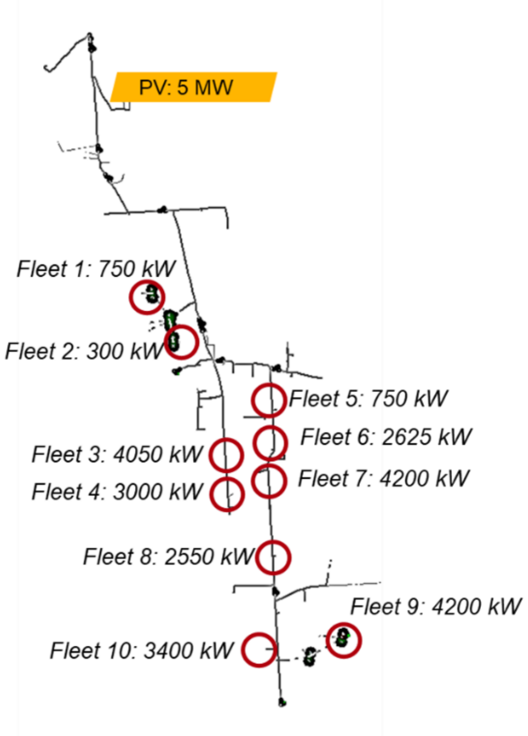
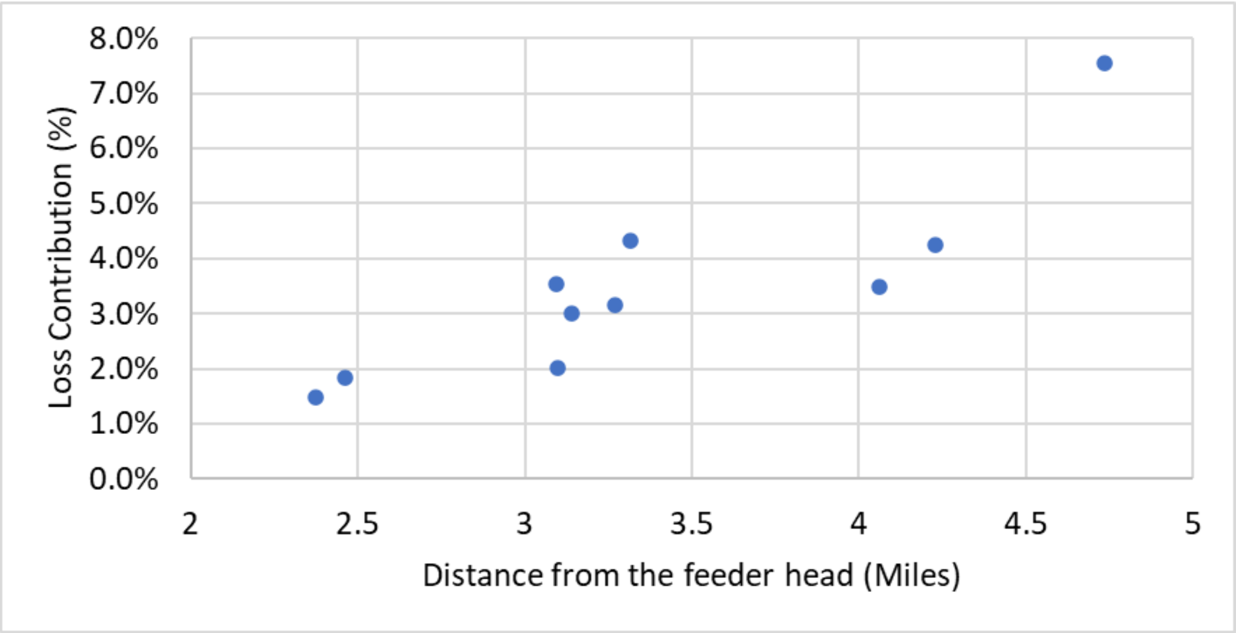


Table 5: Impact of increasing EV penetration level on feeder node voltages

Penetration level	Affected Nodes	Undervoltage %
33%	149	0.92
67%	328	0.85
100%	352	0.79
133%	365	0.73

Active Power Loss



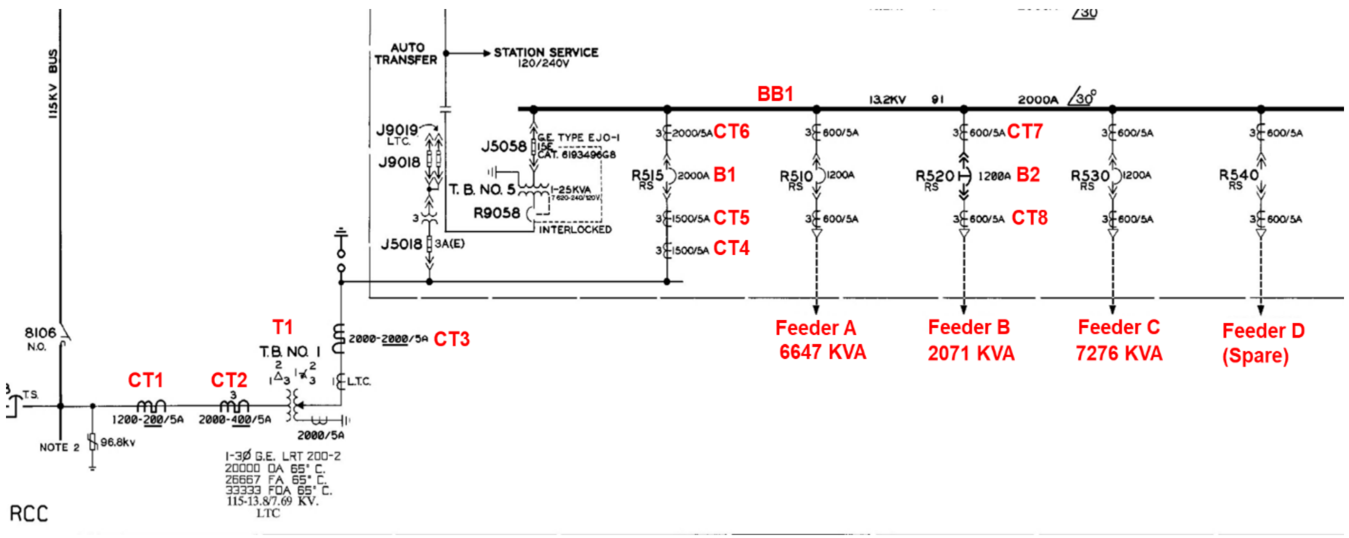


Variation in System Losses with Increasing EV Penetration	
Penetration Level	**Loss (kW)**
0%	19
33%	555
67%	2,169
100%	2,697
133%	4,150

- The existing location of the fleets is agnostic of the grid impacts at 100% electrification of vehicles. Hence, the fleet charging near the feeder end may contribute to higher loss than those near the feeder-head.
- The contribution to the total system losses from the fleets can range from 1.5 to 7.5%.
- The losses further increases with the increasing adoption of EVs due to higher voltage drops.

Substation Impacts

HITACHI
Inspire the Next



- Substation transformer experiences the overload EV penetration of 67%.
- At 100% EV penetration, all substation devices are expected to violate the thermal ratings, thereby indicating a requirement to plan for the upgrade to address the increasing EV penetration.

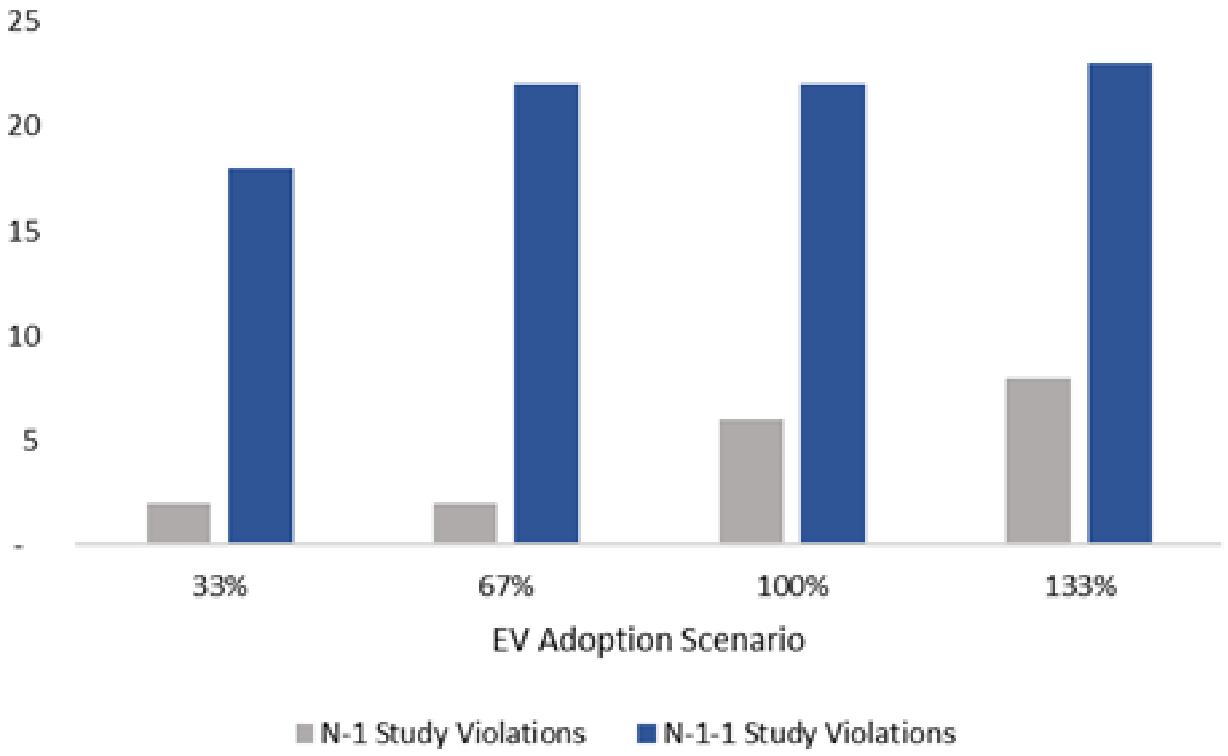
Impact of fleet charging load on the substation device loading

Device	Device Ratings	Overload (%)				
Penetration Level		0%	33%	67%	100%	133%
CT1	1,200 A	55.8	92.5	129.2	167.0	203.7
CT2	2,000 A	33.5	55.5	77.5	100.2	122.2
CT3	2,000 A	33.5	55.5	77.5	100.2	122.2
CT4	1,500 A	44.6	74.0	103.4	133.6	163.0
CT5	1,500 A	44.6	74.0	103.4	133.6	163.0
CT6	2,000 A	33.5	55.5	77.5	100.2	122.2
CT7	600 A	14.4	74.8	135.1	197.3	257.6
CT8	600 A	14.4	74.8	135.1	197.3	257.6
T1	37,000 kVA	43.2	71.7	100.2	129.5	157.9
B1	2,000 A	33.5	55.5	77.5	100.2	122.2
B2	1,200 A	7.2	37.4	67.6	98.7	128.8
BB1	2,000 A	33.5	55.5	77.5	100.2	122.2

National Grid Hitachi Energy

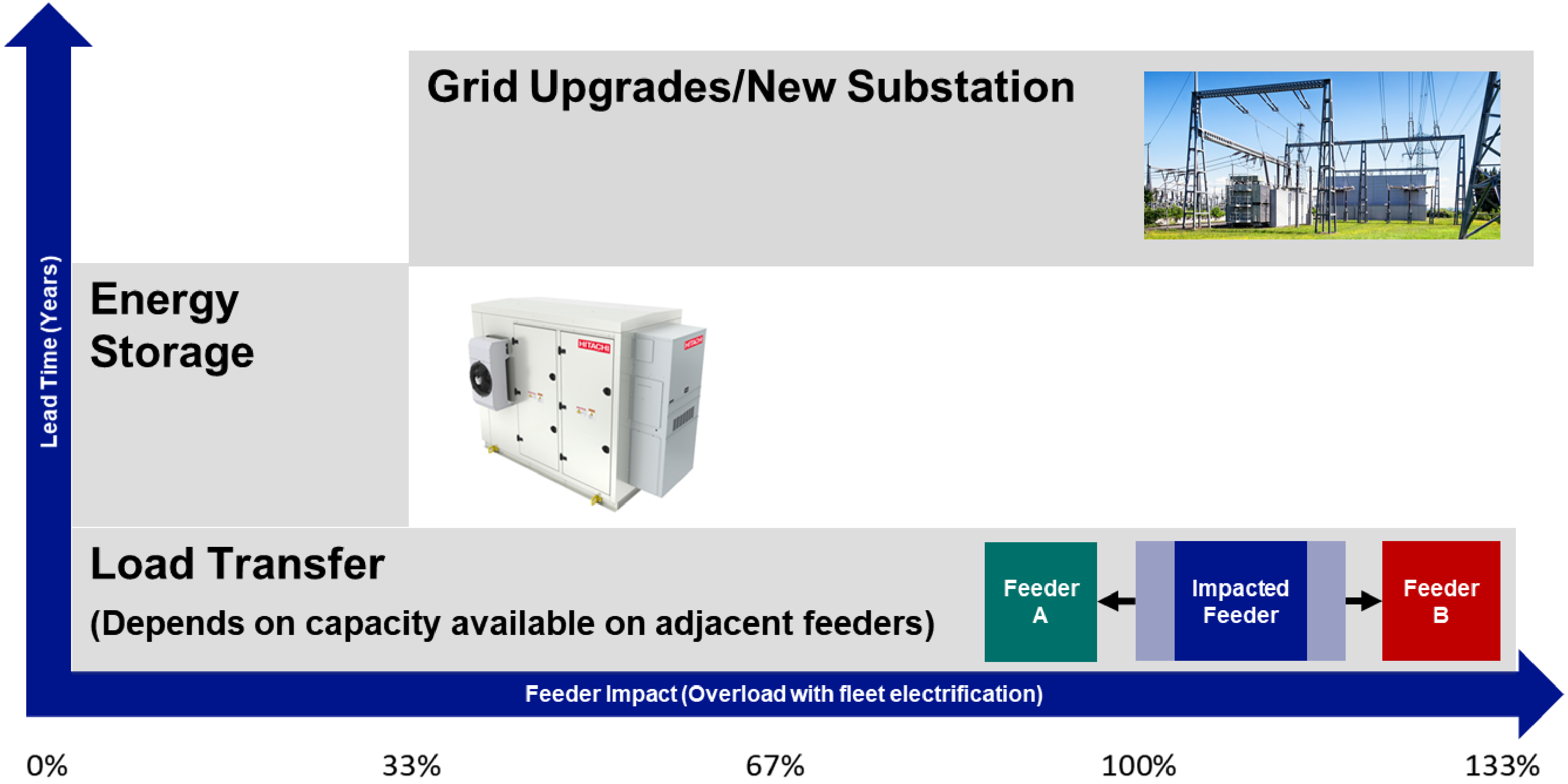
Transmission Level Impacts

- The transmission impacts of EV adoption covering the entire study area were studied under various scenarios to identify N-1 and N-1-1 violations.
- The solutions required for the N-1 violations included the replacement of a current transformer, reconductoring of roughly half a mile of an overhead transmission line and its station connections, and operational changes to prevent further upgrades.
- The solutions required for the N-1-1 violations included reconductoring of multiple miles of both overhead and underground transmission lines, reconductoring of specific station connections, and multiple operational changes to prevent further upgrades.



Mitigation Options

HITACHI
Inspire the Next



Conclusions

HITACHI
Inspire the Next

- Due to the tendency of fleets to “cluster” in industrial areas, load impacts from fleet electrification will be felt acutely at certain areas of the grid.

- Even early stages of fleet electrification could introduce substantial amounts of new electric demand to these areas: at 33% adoption of electric vehicles, peak electric demand in the case study area would more than quadruple.

- At that point, almost half the 5-mile distribution circuit would be overloaded, with some sections reaching 150% of their rating. At higher levels of penetration, the substation components will face overload, as well.

- A mitigation strategy is required to prepare the grids for large scale electrification of the automobile sector. It will be valuable to consider: the time required to implement a given solution; the pace of electrification; cost; and the likelihood of requiring additional upgrades in the future.

National Grid Hitachi Energy

Hitachi Energy

HITACHI
Inspire the Next